archeological ruins scattered throughout. In Sian Ka'an, the objective is to integrate the conservation of these habitats with small-scale human development programs. One such program involves working with a small community of well-organized fishermen who live in the reserve. These fishermen harvest 40–60 tons of spiny lobster tails annually from the reserve and earn a very healthy income in the process. However, this relatively new fisheries, until recently, was developing with very little information on the lobster's population or biology. A plan is now being prepared to better manage and monitor this fisheries to ensure that it continues to be a valuable economic resource for the region. Meanwhile, reserve managers are looking at forest resources in the reserve, such as orchids, that might be harvested sustainably without deleterious effects on the reserve's ecosystem.

The wildlife and wildland management programs just described are part of a clear message coming out of many tropical regions of the world, a message of importance to both those primarily interested in human development and others in the conservation of biological diversity. For development-oriented sectors, the message is that in many tropical regions, especially in tropical forests, development must look towards making use of native plant and animal resources in natural or semi-natural ecosystems because conventional systems of agriculture do not work, and because local people are predisposed to living off native resources. It must be realized, however, that for many tropical forest systems and species, utilization cannot be intensive, but rather must be practiced over relatively extensive areas if resources are not to be over-exploited.

The significance of this message for biological diversity is, in the simplest terms, use it or lose it. This is not to say that strictly protected areas such as national parks do not have a major role in the conservation of wildlife and habitats in the tropics; they do, and indeed national parks and equivalent reserves will continue to be the primary method for protecting areas of exceptional uniqueness and diversity. However, such protected areas can never cover more than 5–10% of a country's territory, and we know that much more extensive areas must remain in natural or semi-natural condition in the world's tropical forests if we hope to conserve the vast array of organisms found there. The question therefore becomes: How do we manage those 90–95% of tropical forest lands outside protected areas? If sustainable use of wildlife resources on these lands cannot be demonstrated, there will be intense pressure to open them up to uses such as logging or slash-and-burn agriculture that are less sustainable and more destructive of the natural systems.

In the past, support for research and development of sustainable use of wildlife resources in the tropics has fallen between the cracks. Development agencies viewed it as too unconventional, underestimated its importance, or simply looked at it as wildlife preservation guised as development. Conservation agencies saw it as too use-oriented or failed to see its overall role in wildland conservation. That situation, happily, is changing, as the crack between development and conservation agencies is narrowing and we see that sustainable wildlife use in the tropics provides a common ground for our objectives of sustainable development and the conservation of biological diversity.

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The Grand Array of Life on Earth

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We hope in this third section, to give a biological perspective, namely how life on earth, and *our* life on earth should relate one unto the other.

First, we should consider life itself, this exceptional development which appears to be confined to our planet alone. Life is a high energy operation, because it takes great amounts of energy to build complex structures—more complex than anything that occurs in the vast segment of our solar system and universe which is non-living. It takes energy, too, to maintain these complex structures against the general tendency of the universe away from structure and toward chaos—so elegantly summed up by Josiah Willard Gibbs as the Second Law of Thermodynamics, but certainly more widely and unwittingly in human cognizance in the lines about Ozymandias, King of Kings.

The necessary energy comes largely from the sun and is converted by green plants into forms usable by them and other forms of life—a miracle that we unconsciously celebrate thrice daily as we go to table, or eschewing ceremony, at least acknowledge by grabbing for a caloric ring, as the merry go round of our lives rushes past a fast food establishment. The order and structure of human achievement, whether libraries, machines, governments or edifices are but extensions of the ability of life to produce order and structure.

But living things are not immortal, they must inexorably succumb to Gibbs' Second Law, yet can manage to escape by the device of reproduction. Life is very much in the business of making more of itself, which is why sex keeps rearing its head. Without meaning to descend to schoolboy snickers and titters, it *is* biologically meaningful that sex is pleasurable—were it not, it is inevitable that the particular species would become extinct. It is reasonable to suppose that reproduction is pleasureable for each form of life on earth. One cannot help but wonder what it must be like for species like the Century Plant for which it only happens once in a lifetime. I dwell on this point not to titillate like a saucy dime store novel, but because this universal feature of life on earth, is also a source of great hope for those of us concerned with maintaining the variety of life on earth. Given a chance, each species will perpetuate itself, but from extinction there is no return, no escape.

We know that life on earth comes in great variety, but science, cannot as yet, say with any precision how diverse life on this planet actually is. When I first became interested in natural history some thirty years ago, the general estimate was on the order of a couple million species. Later estimates of five and ten million began to be heard and just recently based on discoveries about insect life in the rain forest canopy, the estimates have risen to about 30 million (Erwin, pp. 59–75 *in* Tropical Rain Forest: Ecology and Management, S. L. Sutton, T. C. Whitmore, A. C. Chadwick, eds., Blackwell Scientific Pubs., Oxford, 1983). This means that we know the weight of the moon, and perhaps even the strength of the magnetic fields of Uranus, to a greater precision than we have taken the measure of the variety of life—really a most fundamental datum of science, and one of very central interest to ourselves as part of it all (Wilson, Issues in Science and Technology 2:20–29, 1985). This is a very disturbing state of ignorance especially when we are on the verge of losing a major fraction of the variety of life on earth. The impending loss is in large part due to unpremeditated or unwilling actions by an ever larger human population, acting in a variety of environmental destructive ways, prominent among them the destruction of tropical forests which harbor about half of this astounding variety.

The tendency to diversify is a fundamental theme echoed throughout the history of life on earth, checked and occasionally reversed only by traumatic events, such as the meteor induced dust cloud currently believed to have triggered the demise of the dinosaurs (Alvarez et al., Science 208:1095–1108, 1980; Wilford, The Riddle of the Dinosaur, Knopf Div. of Random House, New York, 1985). We have only the most rudimentary notions as to why there is such a universal tendency. It is all too easy to accept it as a fact without understanding, even to say that it really means we needn't concern ourselves with the loss of a species here or there, for after all, with certainty more will eventually arise. Yet such an uncaring attitude ignores that the time scale for replenishment of diversity impoverished by human action, is on a greater scale than a human life span, and will do little good for those of us here now, or even the next generations. Nor does it recognize that each and every species is a reflection of a long evolutionary history, stretching back to the origins of life on earth. Each also reflects recent environmental history and problems, which the extant organisms, by their very survival, have demonstrably dealt with and developed solutions for. These are solutions often of immediate relevance to practical human affairs, whether it be resistance to viral diseases of corn discovered in a wild perennial corn species in the mountains of Jalisco, or the ability to remove mercury or isocyanate from aquatic environments demonstrated for two yeasts in eastern Pennsylvania streams (R. Patrick, pers. comm.).

The tendency to variety also expresses itself on a local level in those biological aggregations of interacting species science calls ecosystems. Almost all natural ecosystems contain large numbers of species, many of which are rare, and the functions of which in the system are either unknown or *apparently* negligible. Yet why do almost all ecosystems have such variety—variety incidentally that is badly diminished in the face of toxic wastes and pollution? A "clean" environment is biologically diverse. A polluted or stressed environment is not, but rather is dominated by dandelions, cockroaches, or equivalent weeds and pests. I, and some others suspect the presence of the variety of species in an ecosystem is, by accident of history or otherwise, a measure of the flexibility of that system in time of change: when mercury contamination lowers the diversity of a stream community the particular yeast species becomes abundant and the ecosystem persists while the yeast busily cleans it up.

Certainly we know enough to say that maintaining biological diversity is almost entirely a matter of plusses for human society. Dependent upon it is the ability of ecosystems to continue to function in ways on which we in turn depend. The life sciences, are surely (without in any sense belittling other fields of inquiry) the most important branch of knowledge for ourselves as living organisms. Understanding them depends squarely on maintaining the basic body of data about life on earth and this is best summed up and measured by the diversity of life on earth. And each and every species holds the promise for discrete highly practical contributions to human welfare—an enzyme or observation can transform the world.

These fundamental truths tend to be obscured by the triumphs and glitter of our technology. And it is hard not to be distracted. When I think of a year spent on Maryland's Eastern Shore as a boy, in a house with a woodstove and a telephone with no dial, it seems nothing short of miraculous to live in a world of microwaves, Concordes and satellite assisted direct international dialing to some of the most remote places on earth. Another fatal flaw will be to let this blind us to our true biological nature, to let us think for example that biological engineering means we can dispense with diversity because we can replace what we have lost—instead of the reality that biological engineering merely increases the value of the biological library that the diversity of life on earth represents. Indeed from another perspective it is very clear that humans are best served by landscapes that are both domestic and wild, and that humans dwelling in biologically impoverished landscapes tend to lead an impoverished existence. The best measure of our success in maintaining a balance between the world of technology and the world of our biological nature, will be the extent to which we protect biological diversity. The wisdom of wildness (to borrow Lindbergh's term) rests on valuing and protecting each and every species, and in protecting that grand array of realized possibilities of living systems that we term so simply: biological diversity.

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Impact of Development on Arid Rangelands

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Biological diversity has been affected adversely by two major forces in recent times. The first is growth of the human population and the second is technological development. Surely the rest of the biological world must regard us as a species that has reached plague proportions demanding vast resources from the land. We have achieved a large part of the support of our enormous numbers through technological capacities to make rapid and large scale changes in the land, changes affecting all of the other organisms sharing the environment with us.

The effects of the large population size and technological development have been to reduce biological diversity and to diminish the capacity of land to support biological systems including those from which we draw our own support. These effects are particularly dramatic as we invade the lands which throughout history have been little altered by occupying cultures because of the difficulties in extracting from these lands resources to support human activities. The major land types greatly affected by current development are the wet tropics and the arid rangelands.

Under most schemes of development the wet tropics experience high rates of loss of the biological diversity that characterizes them. The loss can have catastrophic effects locally on soil structure, nutrient cycles and the interrelationships among many species integral to the stability and productivity of the life forms of these forests. On a large scale the loss is a threat to global climatic patterns and hence potentially effects all biological systems. The richness of the life forms destroyed through this process is not even fully appreciated by science.

In contrast, the arid lands, the other major land types affected by human population growth and development, are characterized by less biological diversity and greater environmental instability than are the tropics. The destruction of these dry lands, however, is no less rapid or dramatic than the destruction of the natural systems of the tropics nor are the long term effects of these losses likely to be of less consequence to the richness of all life dependent on these areas.

The form of development in the dry rangelands is mainly pastoral instead of wood products or crop farming for water is too limited to support growth of timber or allow cultivation of grain crops in most arid areas. The common result of pastoral development is loss of the stability of biological resources.

Dry rangelands have several characteristics in common. Many are in the 30 degree latitudes and are influenced by world wide climatic patterns. They experience low rainfall and high rates of potential evaporation. This water stress is often compounded by irregularity in the timing of rainfalls. These climatic factors present a series of physiological challenges to the perennial plants growing under conditions in which they must struggle to retain the water they have secured against a great evaporative force drawing it out from their leaves and roots. These plants must be able to make use of water entering their environment at any time while on rare ocasions they must survive having their roots flooded with an overabundance of water that takes some time to drain away or evaporate.

An example of this suite of characteristics drawn from the arid zone of South Australia comes from weather records at Brookfield Conservation Park. The average annual rainfall is 260 mm in the face of an average annual potential evaporation of nearly 2000 mm. The rainfall is distributed randomly among the months of the year and in the decade from the middle 1960's to the middle 1970's, registered rainfall fell below 100 mm in 1967 and above 500 mm in 1974. This low, erratic rainfall linked with high predictable rates of potential evaporation concentrated during the summers leads to great challenges to living organisms in hanging on to the water necessary to support life processes. The behavioral, physiological and evolutionary responses of native species are focused on coping with limited water and, in turn, inaccessibility of nutrients. The evolutionary resolution of the water challenges to the arid adapted biological systems of the dry lands is expressed in relatively few and highly specialized species of plants and animals occurring in sparse populations representing these species. The low biomass of organisms is in keeping with limited availability of water. A low biomass is all that can be supported.

Most arid lands have two plant systems. One is the ephemeral plants which are ubiquitous when growing conditions are good. These plants are short lived as visable green plants finishing with their major dependence on water within the brief span during which they have ready access to it. The rest of the time their presence in the system is inobvious as they wait out the dry times in the soil seed bank. As seeds, their metabolic needs for water are few and the threats to their existence relatively reduced. Pastoral profits ride on the ephemeral plants which spend as short a time as possible in making the seeds of their next generation of plants. Their short time spent as green plant seed factories offers only a short time that these plants are available as sources of nutrients and water to mammalian herbivores. Once they have set their seeds, their life cycle is generally complete and they vanish from the landscape even if they have not been grazed away.

The other plant system is that of the perennial plants including the lichens, shrubs, trees and species of long lived grasses. These are the physiological specialistsable to hold onto water while engaging in metabolic activity and retaining water against the large gradient of the potential evaporation. These persistent species are usually very slow growing and set seed only irregularly when favorable climatic conditions arise. They are vulnerable to overuse by grazing and browsing animals. Most of each plant's water and nutrient resources are required for its own persistence under conditions of environmental stress. Few are available for harvest by other species without serious effect on the individual plant providing them. An analogy can be made with a bank account gathering small percentages of annual interest. Small amounts can be withdrawn without loss of the principal. If large amounts are taken, all may be lost in time.

Native mammals in these rangelands generally occur in low numbers or are nomadic, following the availability of the ephemeral plants appearing with the rains. Thus in the natural scheme grazing pressure on perennial plants is light. Histori-